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(54) **Forming three dimensional objects from two-dimensional designs using photopolymerisable compositions**

(57) A sensitive polymerisable composition is imagewise exposed and developed to give a three dimensional form, which is then used in a moulding process. E.g. a wax model is made from the shaped polymer and used to make a metal casting by the lost wax method.

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FIG. 1

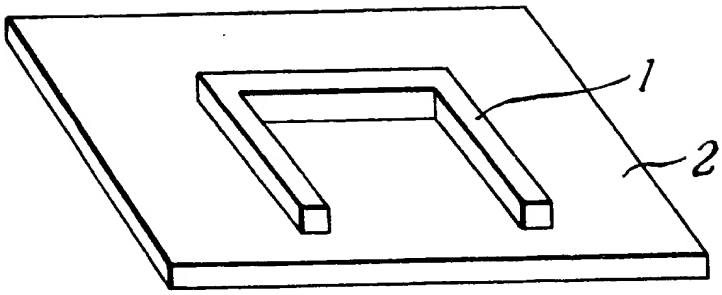


FIG. 2

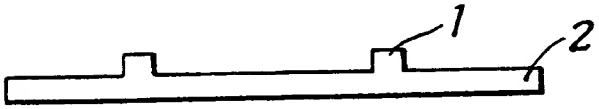


FIG. 3

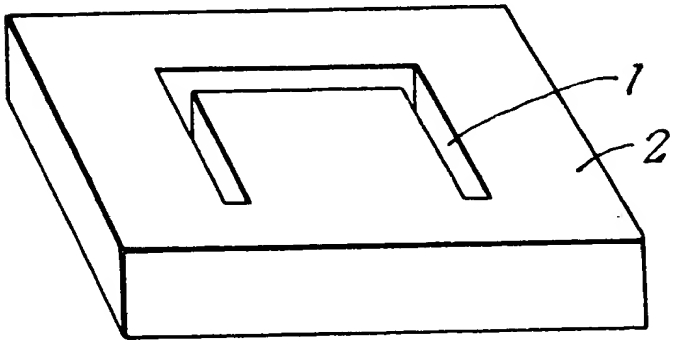


FIG. 4

FIG. 5

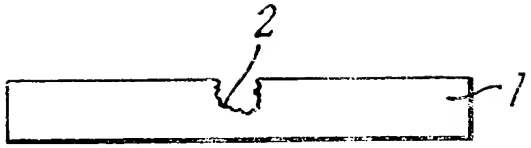


FIG. 6

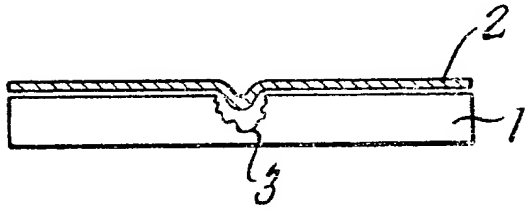


FIG. 7

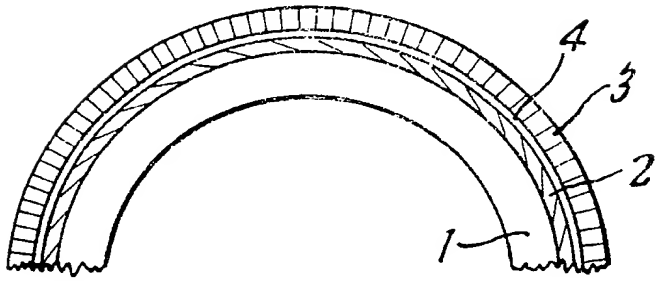


FIG. 8

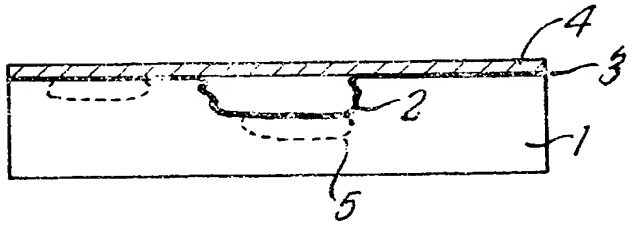


FIG. 9

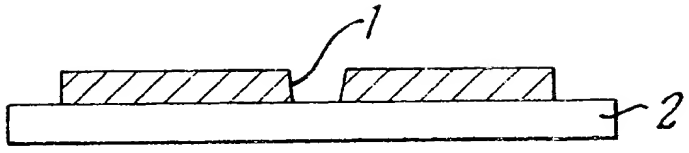


FIG. 10

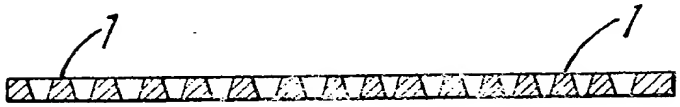


FIG. 11

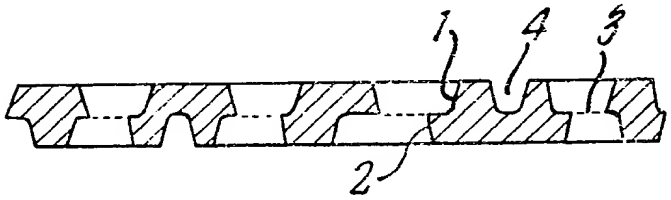


FIG. 12

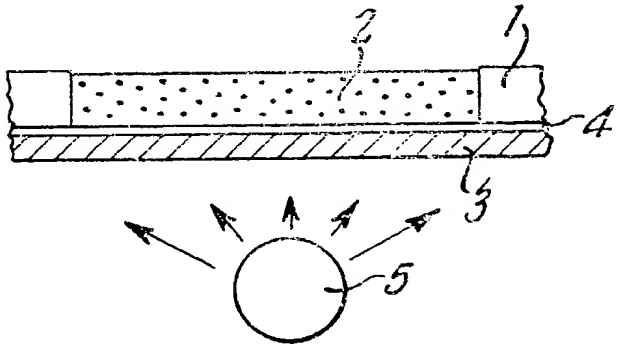
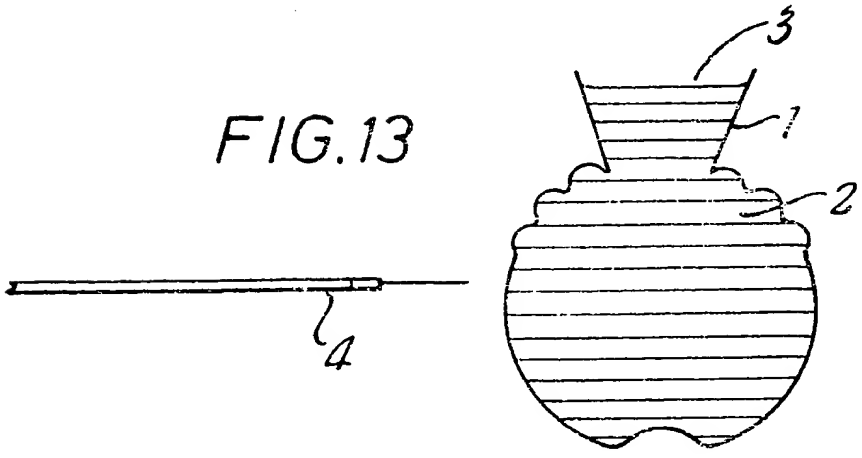


FIG. 13



SPECIFICATION

A method of converting drafted designs into 3-dimensional ornamental objects

This invention relates to an improved method of producing three-dimensional relief or intaglio objects from drawn designs. It is particularly applicable to small items such as jewellery, although it could equally well be applied to the production of ornamental plaques, nameplates and the like which can be produced from a mould by casting.

In particular, the invention describes simple, low cost methods of producing 3-dimensional master patterns from drawn designs which are subsequently reproduced using the lost-wax casting method. In this method, a rubber mould is made from a master pattern; this mould can either be a two-part mould where a reproduction of all faces of the pattern is required, or a simple one-part mould where the pattern of only one surface is required to be reproduced. A wax impression is made from the mould by pouring in or injecting molten wax. This wax impression is then embedded in plaster; on heating the wax disperses into the plaster. The cavity left by the dispersed wax is then filled with molten metal which enters the cavity through a channel. The metal can simply be poured into the cavity or assisted by the action of vacuum pressure or centrifugal force.

The objects could for instance be simple, flat pendants or medallions as shown in figures 1-4 inclusive. In figures 1 & 2, the design 1 stands out from the surface 2 and is described as being in relief. In figures 3 & 4, the design 1 is set into the surface 2 and is described as being intaglio. Traditionally the master pattern for the design shown in figure 1 would be made by shaping and soldering a piece of wire onto a backing plate. The master pattern for the design shown in figure 2 would be made by engraving either by hand or machine into the material. In either case, skilled work is involved. Either master pattern could have been made by covering a piece of metal with a thin layer of acid-resistant material, (usually termed resist), manually removing part of the resist and etching the bared metal.

The profiles of intaglio and relief designs produced by etching would not normally be as clean as the manual methods since the etching tends to cause pitting and undercutting, even when using special etching methods such as "dragon's blood powder etching" or "powderless etching". The results also tend to be somewhat unpredictable and it is difficult to precisely repeat a given result even though the variable conditions appear to be constant. Rubber moulds as previously described could be taken from all these forms of master patterns and waxes produced from them. However, if undercutting is present in etched master patterns, it would prove difficult to subsequently remove the wax impression without distortion. It is also possible that a wax impression of the surface of either 1 or 3 could be taken directly from the pattern in order to form the reverse impression. Here again, any undercutting would make it difficult or impossible to remove the wax.

In recent times, photographic methods have been applied to the etching of metals, particularly in the printing fields. Photo-etching as it is called, consists of coating a metal plate with a light-sensitive resist – usually called "photo-resist" – using a photographic image on film of a drawing (either negative or positive, depending on the type of resist) to cover the plate and exposing it to a suitable light source, usually high in ultra-violet radiation. This has the effect of hardening the resist thus exposed. The remaining unexposed resist is washed off using a suitable solvent.

Photo-etching has been used in the jewellery field for the direct manufacture of metal items from drawn designs. In this case, a carefully drawn artwork is necessary as the line thicknesses have to be carefully controlled during etching. It is possible to etch fully through thin plates by using two precision registered photographic film images, one on each side of the plate and etching from both sides simultaneously. Both producing accurate photographic film images and etching, particularly in precious metals, requires a high level of skill plus elaborate equipment. It can be difficult to produce a neat edge when etching fully through, as the etching usually cuts in to the metal at an angle, which can leave a burr when etching from both sides. The maximum thickness of a plate etched in this way is normally in the region of 1 mm. This method is normally used for the direct mass-production of relatively simple pieces from a flat plate rather than for the production of master patterns since the origination costs can be relatively high and it might be more economical to produce the master pattern by hand. Should a mould and a wax impression be taken, the problems of undercutting and pitting as previously mentioned may cause problems.

Very recently, new materials called photo-polymers have been developed and are commonly used in the printing industry. Their chief characteristic is that there is a relatively thick layer of plastic which is polymerised by the action of light, again usually high in ultra-violet radiation. This action takes place throughout the layer and the unpolymerised plastic can be washed away with a suitable solvent. Because no etching is required, there is no undercutting and the profile of the image is extremely clean with excellent line definition, unlike etched metals. A direct relief or intaglio image can be formed in them simply and quickly with a depth of image of up to 5mm or even more. Photo-polymers are available in sheet form, metal and plastic-backed sheet form and in liquid form. Images formed in these materials are predictable, repeatable and easily controllable.

When considering master patterns produced by the etching or photo-polymer methods, it can be seen that intaglio and relief designs can be thought of as simply reverse images, since exactly the same method is used for producing either. The only difference between producing the relief or intaglio design is the photographic image used. The inventions described hereinafter are equally applicable to both types of design, although in most cases only intaglio

designs are described.

It has been found that by utilising and developing a number of the methods described above, ornamental designs can be reproduced from drawn originals, utilising few of the previously required time-consuming skills. In all instances a photographic or hand drawn image (negative or positive depending on the material used) is used to form a three-dimensional image by etching or photo-polymerisation. A wax is then produced from the three-dimensional image either directly or by using a mould and this wax image is subsequently cast in metal by the lost wax method.

The first aspect of the invention relates to an improved method of taking wax impressions directly from the surface of an etched plate. As previously mentioned, undercutting and pitting commonly occur in etched plates. Figure 5 shows a profile of a line etched into such a plate 1. It can be clearly seen that because of the undercutting and pitting of the etched line 2, if an impression were attempted using molten wax, it would be impossible to remove without damaging the wax. Another disadvantage of etching into metal is the difficulty of obtaining an even depth of etch all over the design and a molten wax impression would show this uneveness. If a rubber mould were made in order to subsequently form a wax impression, this mould would exhibit all the above-mentioned faults. Under this invention however, a sheet of rigid wax is slightly softened by controlled heat and is then gently pushed into the etched plate which has previously been treated with a silicone or similar release agent. By the correct choice of wax type, temperature and pressure, the surface tension of the wax can exert sufficient force to prevent the wax entering into any imperfections of the metal plate. The wax impression exhibits a sufficiently clear definition, a relatively even line and above all, it is easy to remove the wax from the etched plate. Figure 6 shows such a wax sheet 2 pressed into a metal plate 1 with the wax riding over the imperfections 3.

All the methods of producing a master pattern so far described, apply to basically flat objects which are made from a plate. They could of course, be formed to a certain extent after etching to create more complex shapes before making moulds or wax impressions. Close contact between the photographic or other film image and the plate is essential to maintain sharp lines in the reproduction and this is usually achieved by squeezing the film image to the plate using a sheet of glass, preferably held into contact under vacuum. As mentioned above, if a more complex master pattern such as for example, a finger ring, is required, this would have to be produc d by etching a flat plate and subsequently forming this plate into a ring, by butt joining the two ends, normally by soldering. Problems are inevitably encountered by this method, since the solder will flood into part of the etched pattern along the joint. The second aspect of the invention as shown in figure 7, shows a method whereby a ring or similar object can be etched in its made-up state. A ring 1 is first formed (in a metal suitable for etching) and the ring is coated with photo-resist 2. A film image 3 of the pattern is then cemented round the ring utilising a fully transparent adhesive 4. Alternatively, a photographic film such as a stripping film can be used where the emulsion layer on a very thin membrane is removed from its film base and placed directly on the metal – this might prove easier to remove subsequently. The ring should be surrounded by lights during exposure to ensure eveness of exposure. Alternatively, the ring can be turned during exposure to a single light source. After exposure, the film or emulsion is removed carefully to avoid damaging the resist layer, the ring it etched and the resulting patterned ring used as a master model to produce duplicates.

The third aspect of the invention describes a method of producing etched designs of differing levels. This could be achieved by the more primitive method of "stopping off" parts of the design during etching with an acid-resistant medium. Likewise, new lines could be scratched into the existing resist of a partly etched master pattern. Such methods tend to be unpredictable and require great skill to achieve the desired effect. To some extent the etched depth in straightforward etching is controlled by the line width, since narrow lines tend to etch less deeply than broad lines. According to this aspect of the invention – as shown in figure 8, two or more film images are used to produce designs of differing depths. The etching of a plate 1 as in either of the previous methods, results in an etched line 2. The plate is then re-coated with a second coating of resist 3, which is then exposed to a new film image 4 and re-etched. By controlling the etch times, different etch depths can be achieved. Also the second etched design 5 can actually appear within the previously etched design 2; an effect that would be difficult to achieve by other means. It must be realised however, that some broadening of the line would occur where close contact of the film image and the metal was not possible. This effect can also be alleviated by using the previously mentioned stripping film as the film image layer, since the thin membrane will follow the profile of an etched line better than a normal thick film. An alternative method is to coat a sensitised liquid emulsion directly on to the second resist layer 3 and a photographic image is produced on this emulsion by projection printing from a separate negative (or positive). It is also possible to eliminate the contact film (or liquid emulsion) altogether by utilising a sufficiently powerful light source in the projection printer and thus directly hardening the resist layer from the negative (or positive) in the projection printer.

The fourth, fifth and sixth aspects of this invention refer to photo-polymer plates. Since the polymer layer is itself directly hardened by the action of light (especially ultra-violet), no resist layer is required and the film image is placed in direct contact with the photo-polymer layer.

The fourth aspect of the invention utilises a metal-backed photo-polymer plate as shown in figure 9. A design such as produced in the first aspect of the invention is readily produced with a photo-polymer plate and exhibits consistent line definition, a neat wall profile 1 and more especially, perfectly

even depth of etch can be obtained, since the removal of the unexposed polymer can be effected down to the base plate 2, provided the drawn line thickness is sufficient. In the printing industry, this latter effect is not especially significant since it is the top surface which is utilised to effect the print and the virtual impossibility of achieving the effect with a metal etched plate has been of little consequence. However, the perfect depth of etch achieved using a photopolymer plate in the production of ornamental designs is immediately obvious. Owing to the eveness of the photo-polymer image, the previously mentioned method of softening a rigid wax sheet to achieve an even impression is not required and the best results are achieved by using molten wax. The most suitable method is to make a rubber mould of the photo-polymer plate and pour the wax into the mould. The flexible mould allows for subsequent easy removal of the wax. Since a photo-polymer plate would be damaged by the temperature of vulcanising of the rubber required to make a normal rubber mould, special catalysed cold-cure rubber compounds must be used.

The fifth aspect of the invention utilises unbacked photo-polymer material to reproduce the effect of detailed and highly skilled filigree work as shown in figure 10. In this case, the dissolving of the unexposed photopolymer takes place right through the material, leaving a hardened plastic lattice work 1 reproducing the drawn design. (The design will normally be a continuous line work so that the polymerised material remains in one piece, although several pieces may be made and subsequently assembled at the processed photo-polymer, wax or metal stage). A rubber mould as before is produced and the wax impression for casting taken from this. A similar filigree effect could be achieved by the photo-etching method described but with the attendant problems of burred edges and limited thickness.

A development of the "filigree" photo-polymer method is to expose the polymer layer from both sides with different film images to produce a complex double-sided design. By controlling the exposure, the depth of penetration of the light and hence the polymerisation can be can be limited to any desired depth. This type of work is shown in figure 11. In this case the top penetration 1 and the bottom penetration 2 meet half way to merge. Where light penetrates only from one side, an intaglio impression 4 is formed down to the half way level 3. By this means a combined filigree and intaglio design can be produced.

The sixth aspect of the invention is the use of flexible photo-polymers for the production of master patterns. These are available in two forms, plastic plates with a photo-polymer layer attached to a flexible base and as a photo-polymer liquid. In the latter case, the user would normally apply the liquid to a compatible flexible base before exposure. The methods of exposure and treatment are similar to those mentioned in previous examples; however, in the case of the liquid, side walls have to be constructed in order to contain the liquid. The chief advantage in utilising these flexible photo-polymers is that they can be manipulated after processing in the flat state to form complex shapes, although because of their resilience they must be fixed in the desired shape by any suitable means. The liquid form can be used up to a depth of several inches – although this requires a powerful light source to ensure penetration of the light rays. The liquid photopolymer can be utilised to coat a pre-formed 3-dimensional object, the polymerisation being affected by projected light in order to form a complete, patterned, 3-dimensional object from which a rubber mould is taken. The liquid photo-polymer must be sufficiently thixotropic to enable a reasonably thick coating to be applied. Filigree effects as described under aspect five can also be created with liquid photo-polymer as it may be polymerised without affixing it to its usual flexible base. As shown in figure 12, side walls 1 to contain the liquid photo-polymer 2 are constructed on a glass plate 3 on which is placed the film image 4 and exposure from a light source 5 is effected through the glass. The polymerised plastic 2 is then removed for wash-out. It can then be manipulated and fixed by suitable means into the desired shapes for mould making.

The seventh aspect of the invention is the creation of designs in either etched metal or polymerised plates without the use of a film image. According to this aspect, a powerful thin beam light source, high in ultra-violet radiation is used by the designer to directly "paint" a design onto the photo-resist layer or photo-polymer plate. Because of the relatively long exposure, mechanical means can effectively be employed to control the placing and moving of the light beam. A powerful, narrow beam such as produced by a laser might be suitably employed. This type of "light sculpturing" can be applied especially effectively when liquid photo-polymer is utilised in order to construct a complex three-dimensional master pattern. Figure 13 shows in cross section the set-up for producing such a sculptured master pattern. 1 is a container of glass or similar transparent material of the desired shape. The photo-polymer liquid 2 is poured in through an opening 3. A mobile, powerful, narrow-beam light source 4 is utilised to polymerise the liquid as and where required. The greater the time of exposure or the intensity of the light, the greater is the depth of polymerisation. After the required polymerisation has been effected, the transparent container is opened to extract the polymerised material for wash-out. For repeated use a two-part openable container can be constructed, but for a one-off master pattern, a one-piece container may suffice. This has then to be broken open to extract the polymer.

CLAIMS

1. A method of producing a three-dimensional object from a two-dimensional design, comprising forming a three-dimensional image of the two-dimensional design in a photo-polymer material by subjecting areas of the surface of the material in the pattern of the design to photo-polymerisation and removing the un-polymerised parts of the material; forming a master pattern from the image and reproducing an object from the master pattern.

2. The method as claimed in Claim 1, in which the master pattern is in the form of a wax model and the object is cast in metal from the wax model using the lost wax method.

3. The method as claimed in Claim 1 or Claim 2 in which the photo-polymer material is in sheet form.

4. The method as claimed in Claim 3, in which the sheet is backed by a rigid backing.

5. The method as claimed in either Claim 3 or Claim 4, in which one face of the photo-polymer material is covered with the two-dimensional design and exposure of the material to radiation is through the covering.

6. The method as claimed in Claim 3, in which both main faces of the photo-polymer sheet are covered with two-dimensional design parts and both faces are exposed to radiation through the said parts to produce a complex three-dimensional image.

7. The method as claimed in Claim 6, in which the exposures to radiation of both faces of the sheet are such that, at least in some areas, the un-polymerised parts meet to provide apertures in the sheet.

8. The method as claimed in any one of Claims 1 to 4, in which the two-dimensional design is applied to a surface of the photo-polymer material by the use of a light beam.

9. The method as claimed in Claim 8, in which the light beam is guided to form the design by mechanical means.

10. The method as claimed in any one of Claims 3 to 9, in which a rubber mould is formed from the image and the wax model is formed from the mould.

11. The method as claimed in Claim 1, in which the photo-polymer material is a flexible photo-polymer.

12. The method as claimed in claim 10, in which th flexible photo-polymer is in liquid form suitably contained.

13. A method of producing a three-dimensional object from a two-dimensional design substantially as described in any one of the examples herein.

14. A three-dimensional object when produced by the method claimed in any one of the preceding claims.

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